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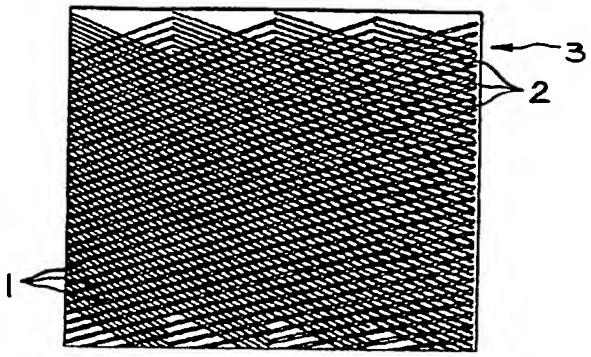

(57) Abstract

A diffractive device has a surface relief structure which, when illuminated by a light source, generates at least two diffraction images which can be observed from particular ranges of viewing angles around the device. At least one surface region (3) has two or more superimposed diffractive surface structures (1, 2), each of which gives rise to a separate diffraction image or component of a diffraction image. The diffractive device is particularly suitable as anti-forgery security device on banknotes, credit cards, cheques, share certificates and other similar documents.

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MULTIPLE IMAGE DIFFRACTIVE DEVICE

This invention relates to a multiple image diffractive device. It relates particularly to a diffractive device which, when illuminated by a light source, generates two or more different diffraction images which are observable from different ranges of viewing angles around the device. Although the device may be used in a number of different applications, it has particular applicability as an anti-forgery security device on banknotes, credit cards, cheques, share certificates and other similar documents.

Several different types of diffractive devices which, when illuminated, generate diffractive images are known. In January 1988, an Australian ten dollar banknote was released featuring a diffractive image of Captain Cook. The diffractive grating used in the image was for the most part comprised of substantially continuous lines, and the shapes and configurations of the lines were determined according to optical catastrophe theory in order to generate fine detail in the diffractive image observed.

International patent application PCT/AU90/00395 discloses an alternative method for generating an optical diffraction image. In this case, the diffractive device is divided into a large number of small diffraction grating structures, each of which upon illumination generates in an image plane a picture element or pixel, with the pixels combining to form an overall image in the image plane. According to preferred aspects of the arrangement disclosed, the respective diffraction grating associated with each pixel comprises a plurality of reflective or transmissive grooves or lines which are usually curved. Groove or line curvature determines both local image intensity (eg. shading) and local optical structure stability. Groove or line spacing in each diffraction grating determines local pixel colour properties, with non-primary colours generated by a pixel mixing. Average groove or line orientation determines

movement or colour effects. The overall surface structure of each diffraction grating is selected from a palette of different grating types having a limited number of distinct values of average curvature and average spacing.

The nature of a diffraction grating illuminated by a single point source of light is normally such that a diffraction image will be observable from particular viewing angles around the diffractive device, whereas the image will not be observable from other viewing angles. The particular ranges of viewing angles at which a diffraction image generated by a diffraction grating is visible depend upon such parameters as the orientation, spacing and shape of the diffraction grating. Two diffraction gratings having different orientations and other parameters can be placed next to each other on the diffractive device with the result that a diffraction image generated by one of the gratings is visible at various viewing angles around the device, whereas a diffraction image generated by the other grating is visible at other viewing angles. A diffractive device which takes advantage of this fact is disclosed in international application PCT/AU93/00102 entitled "Security diffraction grating with special optical effects". That application discloses, inter-alia, a method of using a regular array of small diffraction gratings to form two or more different images which are viewable from different ranges of angles around the diffractive device. One set of diffraction gratings having similar orientations combines to produce one image which is viewable from a particular range of directions. A second set of diffraction gratings, each of which has a second orientation, combines to produce a second image which is viewable from a second range of viewing angles.

A more recent unpublished patent application, Australian provisional application PL 9008 filed 25 May 1993 entitled "Multiple Image Diffractive Device" discloses a similar arrangement, although with each

diffraction grating generating a sub-pixel rather than a complete pixel in the image plane with two or more diffraction gratings combining to generate each complete pixel.

All of the prior art arrangements which produce multiple images require that each diffraction grating portion (whether associated with complete image, pixel or sub-pixel) be dedicated to producing one image (or component of that image) only.

According to the present invention, there is provided a diffractive device having a surface relief structure which, when illuminated by a light source, generates at least two diffraction images which are observable from particular ranges of viewing angles around the device, wherein at least one surface region of the diffractive device has two or more superimposed diffractive surface structures, each of which gives rise to a separate diffraction image or component of a diffraction image.

It is preferred that the diffractive device have the following features:

(a) a set of surface regions have two or more superimposed diffractive surface structures;

(b) one of the superimposed diffractive surface structures in each member of the set generates a component of a diffraction image;

(c) the diffraction image components so generated combine to create a diffraction image which is observable from particular ranges of viewing angles around the device; and

(d) the other superimposed diffractive surface structures in the set of surface regions generate images or image components which are observable from different ranges of viewing angles around the device.

In one embodiment, the diffractive device of the present invention may comprise a regular array of small surface regions in a manner similar to that described in international application PCT/AU90/00395, the contents of

which are incorporated herein by reference. In another embodiment the device may have surface regions in the form of tracks. Another embodiment may use continuous lines shaped and oriented according to optical catastrophe theory as provided in the 1988 Australian ten dollar banknote. Straight line diffraction gratings which generate different diffractive effects by changes in spatial frequency and orientation may also be utilized.

When the diffractive device has a number of surface regions, all of the regions may include superimposed diffractive surface structures, such that each surface region contains a composite surface structure which contributes to more than one of the diffraction images generated by the diffractive device. Alternatively, some of the surface regions may include superimposed diffractive surface structures while other surface regions do not. When the pixels are divided into sub-pixels, some or all of the sub-pixels may be associated with superimposed diffractive surface structures.

The invention will hereinafter be described in greater detail by reference to the attached drawings which show an example form of the invention. It is to be understood that the particularity of those drawings does not supersede the generality of the preceding description of the invention.

Figure 1 is a magnified representation of a small surface region which upon illumination generates a single pixel in the image plane, with the surface structure comprising a series of lines or grooves oriented in one particular manner.

Figure 2 shows another magnified small surface region with the lines or grooves oriented in a manner different from that of Figure 1.

Figure 3 shows a surface region having the surface structure of Figure 1 superimposed on the surface structure of Figure 2.

Figure 4 shows two diffractive tracks, with differently oriented diffractive surface structures.

Figure 5 shows the two surface structures of Figure 4 superimposed onto a single track.

The diffractive device of the present invention has a surface relief structure which, when illuminated by a light source, generates at least two diffraction images which are observable from particular ranges of viewing angles around the device. At least one surface region (3) of the diffractive device has two or more superimposed diffractive surface structures (1,2) each of which gives rise to a separate diffraction image or component of a diffraction image.

In the embodiment illustrated in Figures 1 to 3, there are two overlapping gratings producing two separate optical diffraction images. It is preferred that the individual surface regions be sufficiently small to be below the resolution limit of a human eye (which is about 250 micron). It is preferred that the pixels be less than 125 micron in any linear dimension, and more preferably about 30 micron by 30 micron.

The superimposed diffractive surface structures illustrated in Figures 1 to 3 may have any suitable shape and configuration. They may have straightline gratings, curved line gratings, circular gratings, polygonal indentations or protrusions, or any combination of these. It is especially preferred that at least some of the diffractive surface structures be of the type described in international application PCT/AU90/00395. Expressed in mathematical terms, such pixel gratings are defined by the equation $S(x,y) = kN$, where k is a scaling factor, N is an integer and the function $S(x,y)$ is given by:

$$S_{ij}(x,y) = W_{ij}(x,y) + \beta_{ij}C_{ij}(x,y) \quad \ldots (1)$$

where $S_{ij}(x,y)$ is the initial phase function generated by the grating pixel ij when illuminated normally by a collimated monochromatic light wave,

$W_{ij}(x,y)$ is a carrier wave of non-zero order,

$C_{ij}(x,y)$ is a function of x,y which varies rapidly with respect to x and y and whose Hessian is not identically zero, i.e. does not vanish identically;

β_{ij} is a factor proportional to the assessed chroma or colour intensity of the pixel ij; and

i,j are the co-ordinates of the respective pixels.

The Hessian of $C_{ij}(x,y)$ is a standard complex derivative expressed as follows:

$$\delta^2 C_{ij}(x,y)/\delta x^2 \cdot \delta^2 C_{ij}(x,y)/\delta y^2 - [\delta^2 C_{ij}(x,y)/\delta x \delta y]^2$$

In the embodiment illustrated in Figures 4 and 5, at least part of the surface relief structure is arranged in a series of tracks 4, each track having a diffracting surface 5 which generates a component of a diffraction image. In the superimposed tracks shown in Figure 5, two separate image components are generated. In practice, several such composite tracks are arranged side by side. Two complete diffraction images are formed by combining the image components generated by individual composite tracks.

Each of tracks 2 may be of any suitable length. It is preferred that each track be greater than 500 micron in length, and for the sake of convenience, it is preferred that each track extend throughout the length of the diffractive device, although there is no requirement that this be the case. In the preferred embodiment illustrated, each of tracks 4 is straight and arranged in parallel side-by-side configuration. In alternative embodiments, the tracks may be arranged in concentric circles or sections of concentric circles, or in many other curved arrangements.

Each of tracks 4 may be of any suitable width. It is preferred that the tracks be sufficiently narrow to be not noticeable to the naked human eye. The limit of resolution of a normal human eye examining a diffractive device at close quarters is about 0.25mm. Accordingly, tracks having a width of less than this amount are unlikely to be separately discernible to the human eye.

It has been found that incidental diffractive effects become significant if the width of the track is less than about 4 micron (0.004mm), and accordingly it is preferred that each track be wider than 4 micron.

The diffractive surface structures are preferably produced by means of electron beam lithography.

Prior to the present invention, it had been thought that the superimposition of two diffractive structures in the manner described in this specification would result in interference between the two structures to such an extent that the images produced would be unrecognizable. However, experimentation has revealed that this is not the case, and a superimposed diffractive structure resulting in a plurality of separate clear images can be constructed according to the technique of the present invention.

In the embodiment illustrated, the diffractive structures are all line or groove gratings. However, it is not essential that the structures be comprised of lines or grooves; they may alternatively be comprised of polygons arranged in a manner calculated to cause diffraction.

Australian provisional application PL 9008, the contents of which are herein incorporated by reference, describes a multiple image diffractive device in which each pixel is broken down into component sub-pixels. Each sub-pixel is generated by a tiny diffraction grating and provides some image information, but it is only when the sub-pixels are viewed together that the complete image information for any given pixel is present. By way of example, one sub-pixel might represent a red value, another sub-pixel might represent a green value, another sub-pixel might represent a blue value and a fourth sub-pixel might represent a brightness value, so that the four sub-pixels when taken together give complete brightness and colour information for a complete pixel.

Australian provisional application PL 9008 discloses a method of intermingling the sub-pixels of two

separate pixels having different orientations and contributing to a different final image. The present invention may be used in conjunction with sub-pixels so that any given diffractive surface region may be comprised of two overlaid diffraction gratings, one referable to a sub-pixel portion of each of two images.

It is to be understood that various additions, alterations and modifications may be made to the parts previously described without departing from the ambit of the invention.

CLAIMS:

1. A diffractive device having a surface relief structure which, when illuminated by a light source, generates at least two diffraction images which are observable from particular ranges of viewing angles around the device, wherein at least one surface region of the diffractive device has two or more superimposed diffractive surface structures, each of which gives rise to a separate diffraction image or component of a diffraction image.

2. A diffractive device according to claim 1 wherein:
(a) a set of surface regions have two or more superimposed diffractive surface structures;
(b) one of the superimposed diffractive surface structures in each member of the set generates a component of a diffraction image;
(c) the diffraction image components so generated combine to create a diffraction image which is observable from particular ranges of viewing angles around the device; and
(d) the other superimposed diffractive surface structures in the set of surface regions generate images or image components which are observable from different ranges of viewing angles around the device.

3. A diffractive device according to claim 1 or claim 2 having a plurality of surface regions in the form of tracks, at least some of the tracks having two or more superimposed diffractive surface structures.

4. A diffractive device according to claim 1 or claim 2 having a regular array of small surface regions, at least some of the surface regions having two or more superimposed diffractive surface structures.

5. A diffractive device according to any one of claims 1 to 4 wherein at least some of the diffractive surface structures comprise substantially parallel grooves.

6. A diffractive device according to claim 5 wherein at least some of the grooves are curved.

7. A diffractive device according to any one of claims 1 to 4 wherein at least some of the diffractive surface structures comprise indentations in the form of geometrical shapes other than substantially parallel grooves.

8. A diffractive device according to claim 3 wherein each track is between 4 and 250 micron in width, and greater than 500 micron in length.

9. A diffractive device according to claim 4 wherein each small surface region is between 4 and 250 micron in both width and length.

10. A diffractive device substantially as hereinbefore described with reference to the drawings.

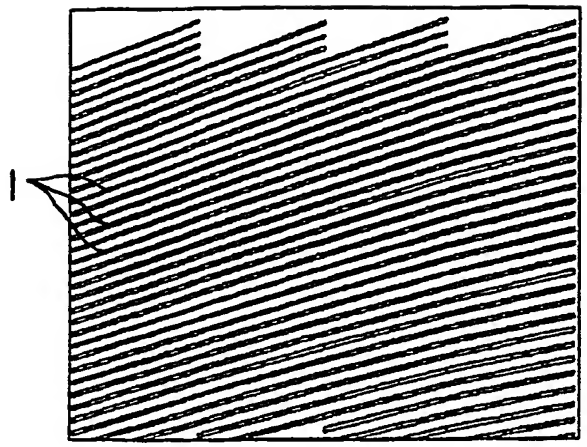

FIG 1

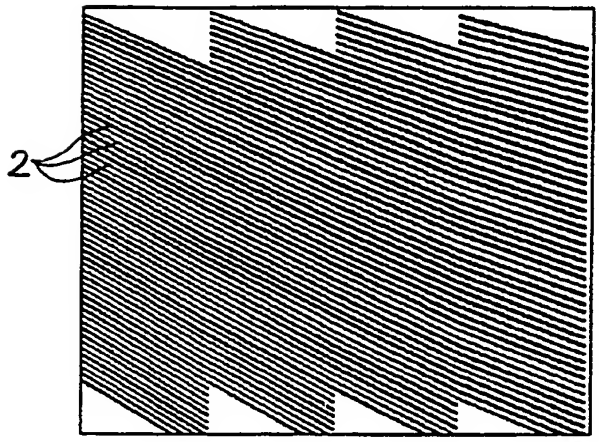

FIG 2

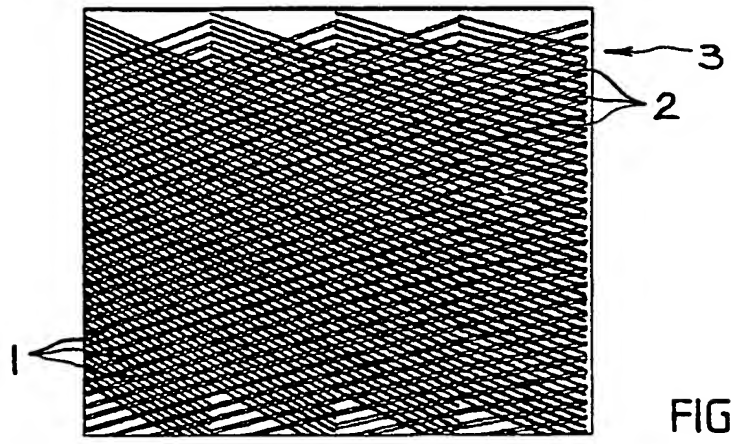

FIG 3

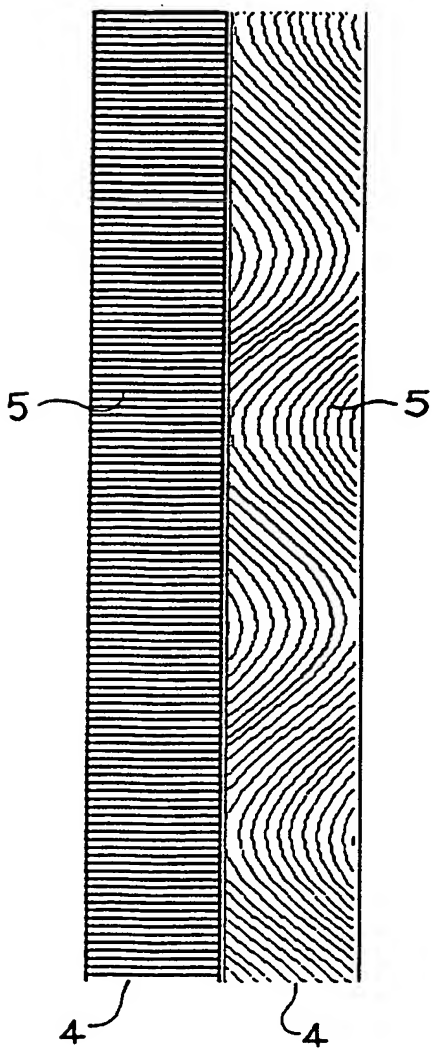

FIG 4

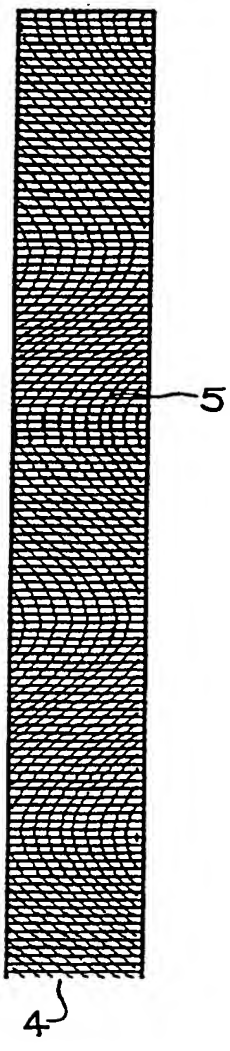

FIG 5

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU 94/00381

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl.[6] G02B 5/18, 27/44, B44F 1/12, B42D 15/10, 209:00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC : G02B 5/18, 27/44, 27/38, B44F 1/12, B42D 15/10, 209:00, 15/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
AU : IPC as above

Electronic data base consulted during the international search (name of data base, and where practicable, search terms used)
DERWENT : DIFFRACT; STRUCTURE; SUPERIMPOSE, ADD
JAPIO : DIFFRACT; STRUCTURE; SUPERIMPOSE, ADD

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to Claim No.
X	GB 1352001 (BALZERS) 1 May 1974 (01.05.74) page 2 lines 29-44, Fig 2	1,5
A	US,A, 5032003 (ANTES) 16 July 1991 (16.07.91) column 2 lines 6-24, column 3 lines 10-23, column 6 lines 6-46, Fig 1,2	
A	US,A, 4402571 (COWAN et al) 6 September 1983 (06.09.83) column 1 lines 32-64, column 4 lines 36-53, column 4 line 63 - column 5 line 5, Fig 1	

(continued)

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
5 October 1994 (05.10.94)	18 Oct 1994 (18.10.94)
Name and mailing address of the ISA/AU AUSTRALIAN INDUSTRIAL PROPERTY ORGANISATION PO BOX 200 WODEN ACT 2606 AUSTRALIA Facsimile No. 06 2853929	Authorized officer M.E. DIXON Telephone No. (06) 2832194

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INTERNATIONAL SEARCH REPORT

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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate of the relevant passages	Relevant to Claim No.
A	US,A, 4155627 (GALE et al) 22 May 1979 (22.05.79) column 3 lines 16-30, Fig 2	
A	AU,A, 44840/64 (EASTMAN KODAK COMPANY) 25 November 1965 (25.11.65) whole document and in particular page 16 lines 17-20	
A	EP,A, 467601 (APPLIED HOLOGRAPHICS CORPORATION) 22 January 1992 (22.01.92) column 3 line 50 - column 4 line 2, Fig 2	
A	EP,A, 240261 (XEROX CORPORATION) 7 October 1987 (07.10.87) page 2 lines 21,22,42,43; page 4 lines 48-52; page 6 lines 26-28, Fig 2,3,7	

INTERNATIONAL SEARCH REPORT
Information on patent family me. :rs

International application No.
PCT/AU 94/00381

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Patent Document Cited in Search Report		Patent Family Member					
US	5032003	AT	85555	DE	58903532	EP	375833
		JP	2165987				
US	4402571	NIL					
US	4155627	NIL					
GB	1352001	CH	505394	FR	2101250	NL	7013207
		NL	145052				
EP	467601	JP	6075107	US	5291317		
EP	240261	JP	62232615	US	4737448		
							END OF ANNEX